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The production diversity of subsistence farms in the Bolivian Andes is associated with the quality of child feeding practices as measured by a validated summary feeding index

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Abstract
Objective: To determine the validity of a summary infant and child feeding index (ICFI) and the association with the index of factors related to agricultural production.
Design: A cross-sectional survey in eight health-post jurisdictions identified as priority nutrition regions. All households with children aged 6–23 months in eligible communities were administered an integrated survey on agricultural production and nutrition-related practices. Quantitative 24 h dietary recall, food frequency data and anthropometric measurements were collected for each child. Ninety-one per cent of eligible families participated.
Setting: The northern region of the Potosí department in the Bolivian highlands.
Subjects: Two hundred and fifty-one households with children aged 6–23 months.
Results: In multiple regression models controlling for potential confounding variables, infant and young child feeding (IYCF) practices as measured by an ICFI showed positive associations with child length-for-age *Z*-score (mean difference of 0·47 in length-for-age *Z*-score between children in the high ICFI tertile compared with the low tertile), child energy intake (mean difference of 1500 kJ between tertiles) and the micronutrient adequacy of child diets (mean difference of 7·2 % in mean micronutrient density adequacy between tertiles; $P < 0·05$). Examining determinants of IYCF practices, mother's education, livestock ownership and the crop diversity of farms were positively associated with the ICFI, while amount of agricultural land cultivated was negatively associated with the ICFI. Crop diversity and IYCF practices were more strongly positively correlated among households at high elevations.
Conclusions: Nutrition-sensitive investments in agriculture that aim to diversify subsistence agricultural production could plausibly benefit the adequacy of child diets.

Keywords
Infant and child feeding
Child anthropometry
Agriculture
Crop diversity
Nutrition

In 2011, at least 165 million children under the age of 5 years suffered from linear growth faltering worldwide, a consequence of chronic undernutrition[1]. Chronic nutritional deficiencies in childhood can lead to an increased risk of morbidity and mortality[2,3], as well as impaired growth and cognitive development, diminished reproductive and work capacity, poor school performance, lowered income-earning potential and an increased risk of several adult-onset chronic diseases[4,5]. The diets of children in their first years are predominantly determined by the decisions and behaviours of their mothers and other household members who feed and care for them. Caregivers' breast-feeding and complementary feeding practices then are essential to the healthy growth and development of children early in life.

Providing education, counselling and complementary foods to caregivers has been shown to improve infant and young children feeding (IYCF) practices in many settings[6]. However, very little evidence is available to evaluate nutrition-sensitive approaches to improving these practices; that is, approaches that aim to address the underlying causes of child undernutrition rather than the immediate determinants[7]. Agricultural-sector interventions have traditionally aimed to improve agricultural yields, animal production and incomes from agriculture. These programmes and interventions have rarely included improving nutrition as an explicit objective. Hence, nutrition-sensitive approaches to improving nutrition through the agricultural sector have been limited overall, and those that have been implemented have focused

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predominantly on increasing food availability and raising household incomes[8]. Yet, agricultural production and the farming livelihoods that agriculture supports may strongly influence the capacity of caregivers to meet recommended IYCF practices. Depending on the extent to which a household's diet consists of foods that the household produces itself, the diversity of crops and animals reared could directly influence the diversity of child diets[9]. The income generated from agriculture may also influence child diets to greater or lesser extents depending on who controls the income[10,11]. In addition, the labour caregivers devote to agriculture, both the amount and nature of the labour, can affect time available for feeding, the kinds of foods that are able to be fed, the responsiveness of the caregiver to the child, the quality of feeding environments, and the health and nutritional status of the caregiver herself[12,13].

These multiple pathways of influence emerge because child feeding is complex and encompasses multiple dimensions. The diversity of the diet, the texture and nutrient density of complementary foods, the maintenance of exclusive and partial breast-feeding and the manner and frequency with which foods are fed are all components of child feeding[14]. Appropriate child feeding practices also change over time. As children get older they adapt to different food textures and require more frequent meals and a larger variety of foods. Therefore, measuring the quality of IYCF practices is challenging. While the set of IYCF indicators developed by the WHO[15] is incredibly valuable for describing IYCF practices globally and advocating for increased attention to child feeding, these indicators may lack sensitivity and specificity and may not be the best tools for all uses[16].

One previous tool used to assess IYCF practices, a child feeding index, derives separate scores for distinct child feeding behaviours and combines these scores into a single, age-specific summary index[17]. If positive child nutrition outcomes are associated with some minimum number of proper child feeding and care practices, a summary index would be more likely to detect these associations than would a measure of any single practice[18].

In the present study we examine the determinants of IYCF practices in a rural, agricultural region of the Bolivian highlands using a summary infant and child feeding index (ICFI) derived from quantitative dietary data. We first aim to determine the validity of the ICFI by examining its association with child anthropometry and the adequacy of child diets. We then seek to identify the determinants of IYCF practices in this region of Bolivia using an integrated data set that includes comprehensive data on household agricultural production as well as the health and nutritional status of children and other household members. We hypothesize that the nature and extent of agricultural production in sample households will influence the quality of caregivers' IYCF practices.

Materials and methods

Study setting

The mean prevalence of stunting (i.e. height-for-age *Z*-score <-2) in children under 5 years of age in Latin America is lower than in most other world regions at 11·7 % (compared with a prevalence of stunting in sub-Saharan Africa and South Asia of approximately 40 %)[19]. Bolivia, however, remains well below Latin American regional averages in many health, nutrition and development indicators. More than one-quarter of under-5 children in Bolivia are stunted (27 %), with an especially high burden in rural areas (37 %)[20]. The northern region of Bolivia's Potosí department where the current research was conducted is one of the poorest and most isolated regions of the country, with a high prevalence of extreme poverty, household food insecurity and high rates of child mortality[21]. The inhabitants of this highland region are predominantly farmers and herders engaged in subsistence agriculture. Food availability, the kinds of crops grown, the amount of land available for raising crops and pasturing animals, and certain farm management practices vary across agroecological zones in the region that are differentiated primarily by elevation and seasonal temperatures. Nearly all households grow potatoes, although cultivation is more extensive at elevations above 3200 metres above sea level (masl). Maize is grown in lower and middle elevation zones between 2700 and 3500 masl, wheat below 3600 masl and barley at high elevations up to 4200 masl. Nearly all households raise mixed herds of sheep and goats with llamas being herded only at higher elevations. Women are responsible for tending to these flocks in addition to their many other agricultural and domestic responsibilities that include planting, harvesting and maintaining crops, preparing food, collecting firewood and water, and caring for children and elderly family members. The IYCF practices of caregivers generally do not meet recommendations. In many households, complementary foods fed to young children are nutrient-poor, are not prepared so that young children can easily eat the foods, are not fed frequently throughout the day, and children are not often assisted while eating or are not fed in environments where feeding is the focal activity[22]. Similarly, children are rarely exclusively breast-fed beyond 3 months of age and any breast-feeding is often terminated by 15 months of age.

Data collection and sampling

In March 2009, a survey of 331 households with children aged 0–23 months was conducted in forty-four communities aligned with eight health-post jurisdictions that were identified by the Bolivian Ministry of Health as high-priority regions for improving maternal and child nutrition. All communities containing five or more households with children aged 6–23 months were included in the sample (*n* 252). Community census data from health posts were used to ensure all eligible communities were included. These data were then verified with community authorities using current household roster data.

Four teams of enumerators administered the survey to mothers and heads of household using questionnaires programmed into hand-held computers (ASUS MyPal A696) for direct data capture. The use of these computers allowed for immediate data access during nightly data cleaning and review sessions with survey teams. Communities were visited by survey enumerators on multiple days to ensure all eligible families were offered the opportunity to participate in the study. Ninety-one per cent of eligible families participated. All but one of the households that did not participate in the survey were engaged in temporary wage or reciprocatory labour outside their communities and were not available for interview.

Infant and child feeding index

An ICFI was constructed based on previously published summary feeding indices[17,18]. Formative research indicated that the diversity of child diets and frequency with which meals and snacks were fed to children in northern Potosí were frequently not meeting recommendations. However, the responsiveness of caregivers to children during feeding and the consistency (i.e. texture) of foods fed to children were also often inadequate[22]. Therefore, the ICFI was adapted to include component indicators of all of these practices (Table 1).

The food groups for the 24 h dietary diversity and 7 d food group frequency components of the index were modified to reflect the food groupings of the WHO minimum dietary diversity indicator[15]. Dietary diversity and food group frequency scores were calculated using data from quantitative 24 h dietary recalls and 7 d food group frequency questionnaires collected using standard methods[23,24]. Data on the type, amount, consistency and preparation method of foods fed to children, including foods fed outside the home, as well as the amount left unconsumed by children were collected during 24 h dietary recall interviews to estimate children's dietary intakes on the day preceding interviews. Standard serving dishes were presented to caregivers so that they could directly indicate the amount of food served to the child as well as the amount left in the child's dish after finishing the meal. Photographs depicting solid, semi-solid foods and porridges of varying consistencies (i.e. from watery to dense and viscous) that are commonly fed to young children in the region were shown to respondents to determine, for each food, the consistency of the final preparation fed to the child. The frequency with which foods and snacks of different consistencies were fed was calculated from these data. Age-specific index score cut-offs based on distributions of 24 h dietary diversity data and 7 d food group frequency consumption data were used to calculate dietary diversity and food group frequency scores.

The feeding frequency scoring criteria of the ICFI closely reflect those of the WHO minimum meal frequency indicator (i.e. breast-fed infants aged 6–8 months should receive solid, semi-solid or soft foods at least two times per day and breast-fed children aged 9–23 months

Table 1 Component practices and scoring of the infant and child feeding index (ICFI)

Variable	6–8 months	9–11 months	12–23 months
Breast-feeding (24 h)	No = 0 Yes = 2	No = 0 Yes = 2	No = 0 Yes = 1
Bottle use (24 h)	No = 1 Yes = 0	No = 1 Yes = 0	No = 1 Yes = 0
Food group diversity (24 h)†	0 food groups = 0 1–2 food groups = 1 ≥3 food groups = 2	0 food groups = 0 1–2 food groups = 1 ≥3 food groups = 2	food groups = 0 2–3 food groups = 1 ≥4 food groups = 2
Food group frequency (7 d)‡	Sum of 0–1 = 0 Sum of 2–3 = 1 Sum of ≥4 = 2	Sum of 0–2 = 0 Sum of 3–5 = 1 Sum of ≥6 = 2	Sum of 0–3 = 0 Sum of 4–6 = 1 Sum of ≥7 = 2
Food consistency (24 h)	Liquids only = 0 Semi-solid or soft foods = 1	Liquids or soft foods only = 0 Semi-solid or solid foods = 1	Liquids or soft foods only = 0 Semi-solid or solid foods = 1
Feeding frequency (meals and snacks) (24 h)	0 times = 0 1 time = 1 ≥2 times = 2	0 times = 0 1–2 times = 1 ≥3 times = 2	times = 0 2 times = 1 3 times = 2 ≥4 times = 3
Responsive feeding (24 h)	Did anyone help the child to eat? Yes = 1 No = 0	Did anyone help the child to eat? Yes = 1 No = 0	Did anyone help the child to eat? Yes = 1 No = 0
Minimum/maximum	0/11	0/11	0/11

24 h, based on 24 h recall; 7 d, based on 7 d recall.
†Sum of: cereal grains, roots, tubers; legumes and nuts; dairy products (milk, yoghurt, cheese); flesh foods (meat, fish, poultry and liver/organ meats); eggs; vitamin A-rich fruits and vegetables; other fruits and vegetables (received or did not receive each food/group).
‡Each food group is scored as 0 if not given at all in the previous 7 d, 1 if given on 1–3 d and 2 if given on ≥4 d. These scores are then summed to give a possible range of 0 to 14.

should received these foods at least three times per day). The feeding frequency component indicator of the ICFI that we use includes data on the frequency with which solid and semi-solid foods were fed to children as well as soft foods and thick porridges. Feeds that consisted entirely of liquids or watery porridges were not considered true meals or snacks for purposes of calculating this indicator. Because we consider thick porridges in addition to solid, semi-solid and soft foods in the calculation of this component indicator though, it may differ from the WHO minimum meal frequency indicator for some children. We examine as a separate component indicator whether solid or semi-solid foods in particular were fed in the previous day. Current recommendations to practise exclusive breast-feeding to 6 months of age and continue breast-feeding to at least 2 years of age[25] informed the breast-feeding and bottle-feeding components of the ICFI. The responsive feeding and food consistency components of the index were based on current recommendations for complementary feeding of young children[14] and were adapted from similar components used in previously published studies using summary feeding and care indices[26,27].

The continuous ICFI score (0–11) was divided into age-specific feeding tertiles in models examining the association of the ICFI with child anthropometry and dietary adequacy. Although creating tertiles from the ICFI score is an arbitrary division of the data and results in loss of information, we carried out our analyses using these tertiles (Table 3) to facilitate comparisons with previous authors' analyses using ICFI tertile groupings.

Dietary adequacy

Child energy and nutrient intakes were estimated using 24 h recall data combined with data from the Bolivian Food Composition Table[28]. The micronutrient adequacy of child diets was assessed using nutrient densities (amount per unit energy of complementary food) as previously described[29,30]. Individual nutrient densities were calculated as the nutrient intake divided by the child's total energy intake (MJ) in the previous 24 h. This amount was then divided by the recommended nutrient density calculated by dividing the RDA for the nutrient[31] (i.e. the Estimated Average Requirement plus 2 SD) by the child's age-specific energy requirement from complementary foods assuming an 'average' breast milk intake[32]. The RDA was adjusted by subtracting out the amount of the given nutrient consumed from an 'average' intake of breast milk to provide an estimate of the RDA from complementary foods only. When RDA data were not available, Adequate Intakes were used. Estimates of recommended energy requirements for infants and children aged 6–23 months were based on data from developing countries that accounted for breast milk intake[32].

The Bolivian Food Composition Table was incomplete for Zn and folate; food composition data for these two micronutrients were imputed from the Peruvian Food Composition Table[33]. In total, the individual micronutrient density adequacy scores of nine key micronutrients (thiamin, riboflavin, niacin, folate, vitamin C, vitamin A, Fe, Zn, Ca) were averaged and capped at 100 % to create a mean micronutrient density adequacy (MMDA) score for each child.

Anthropometry

Child lengths were measured by survey enumerators trained in anthropometry using locally manufactured replicas of child measuring boards (Shorr Productions, Olney, MD, USA) and child weight data were collected using Seca spring scales (Seca Medical Scales and Measuring Systems, Hamburg, Germany) calibrated daily using standardized weights and recalibrated between individual weighings. Intra- and inter-anthropometrist errors in measuring child length were assessed during anthropometry reliability trials[34] prior to survey implementation. Mean intra- and inter-observer measurement imprecision for child length for the four survey teams, expressed as the technical error of measurement, were 0·19 and 0·33, respectively. These figures are within the upper limits of total technical error of measurement for a high level of reliability[35]. Length-for-age *Z*-scores (LAZ) were calculated in the statistical software package Stata version 12·1 using macros provided by the WHO based on data from the Multicentre Growth Reference Study[36].

Other variables

Socio-economic status

An index of household socio-economic status (SES) was generated using a principal components analysis. Thirteen continuous variables, selected *a priori* based on formative research with communities to identify locally relevant indicators of wealth, were transformed to approach normally distributed variables and then standardized to account for differences in unit scales. Measures of land and animal ownership, agricultural production, utilization of health services, access to improved sanitation and household size were included. Factors with eigenvalues ≥1 were first rotated using a varimax rotation and then divided into tertile groupings for inclusion in statistical models as three-level discrete variables. Two extracted factors were included as covariates in analyses performing the regression of LAZ, energy intake and MMDA *v.* the ICFI. Agricultural yields and land and animal ownership demonstrated the highest factor loadings for the first factor, while household utilization of health services and household size had the highest factor loadings for the second factor.

Household food insecurity

Household food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS) for

Measurement of Food Access[37]. The generic nine-item HFIAS questionnaire measures three domains of food insecurity including: (i) anxiety and uncertainty about food access; (ii) insufficient food quality; and (iii) insufficient food intake. We adapted the questionnaire to the local Bolivian context through key informant interviews with community leaders and focus group discussions with families. The continuous, 27-point HFIAS score was used in analyses.

Agricultural production and assets data

Respondents identified all plots of land on which they planted crops during the previous sowing season and reported the amount of each crop that was planted. Farm diversity was calculated based on the total number of different crop species planted including in homestead gardens. Total area cultivated was calculated based on empirically measured seeding rates of each crop. Households also reported the total number of livestock owned of each species. The latitude, longitude and elevation of each household were recorded using Global Positioning System software (SiRE Star III chipset GPS; SiRF Technology, San Jose, CA, USA).

Maternal knowledge of recommended infant and young child feeding practices

We used a ten-item questionnaire to assess mothers' knowledge of several domains of recommended IYCF practices for children of different ages between 6 and 23 months, including initiation of breast-feeding, duration of exclusive breast-feeding and any breast-feeding, responsive feeding, dietary diversity, texture of complementary foods, feeding frequency and feeding during illness.

Statistical analysis

We used ANOVA and Pearson χ^2 tests for assessing differences in means and proportions of sample characteristics, respectively, across elevation zones. We assessed the internal consistency of the ICFI using Cronbach's α coefficient and determined the correlation of individual index items with an index composed of all other component items. All multiple regression analyses were conducted using mixed-effects models (the xtmixed command in Stata) that included a community-level variable as a random effect to account for the clustering of households within communities. Multiple regression models that performed the regression of child LAZ, energy intake and dietary micronutrient adequacy *v.* the ICFI controlled for several covariates including child age, child sex, report of the child experiencing diarrhoea symptoms in the previous two weeks, maternal education level, maternal height (only in models using child LAZ as the dependent variable) and household SES. Models were run separately for each dependent variable and for children 6–11 months, 12–23 months and all children 6–23 months combined. Models that performed the regression of the summary ICFI score *v.* potential determinants of the score included the following independent variables: child age, child sex, report of the child experiencing diarrhoea symptoms in the previous two weeks, maternal education level, maternal knowledge of recommended IYCF practices, number of children in the household, household access to electricity, distance to nearest health facility, household food security, number of livestock owned by the household, crop diversity of household farm, amount of agricultural land cultivated by the household and household elevation. These variables were each included as main effects to examine their individual associations with the ICFI. We tested two-way interaction terms based on *a priori* hypotheses from formative research and field observations about the relationship between child feeding practices and nutrition outcomes, as well as potential determinants of the IYCF practices. Significant interaction terms were included in the final models along with the main effects of every potential confounding variable. Standard assumptions of homoscedasticity and normality of errors were tested for all models. All statistical analyses were performed using Stata version 12·1. Associations were considered significant at $P < 0·05$.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all data collection involving human subjects was approved by the Cornell University Institutional Review Board for Human Participants. Verbal informed consent was obtained from all individuals surveyed. Consent was witnessed and formally recorded.

Results

Sample characteristics

Of the 331 households in the baseline survey, 252 had children aged 6–23 months. Six of these households had two children in this age range. One child was randomly selected from each of these six households to be included in analyses. One additional observation was excluded because of unreliable birth date data. Therefore, data on 251 children aged 6–23 months from 251 households were included in final analyses.

While less than one-fifth of children in the sample were underweight in any elevation zone, approximately half of all children suffered from linear growth faltering (Table 2) with a mean LAZ of −2·0 (SD 1·2) in mid and high elevations and slightly higher LAZ, mean −2·2 (SD 1·3), in low elevations. Nearly all of the mothers interviewed (87–96 %, depending on elevation zone) either never attended school or never finished primary school and a large proportion of women did not visit a health clinic or hospital for antenatal checkups during their most recent pregnancy (39–50 %, depending on elevation zone). Household access to electricity ranged from 12 % at low

Table 2 Child, maternal and household-level characteristics of the sample by elevation zone and IYCF practices by child age range, northern region of Potosí department, Bolivian Andes, March 2009†

	Elevation zone‡					
	Low		Mid		High	
Sample characteristics	Mean	SD	Mean	SD	Mean	SD
Child characteristics						
Age (months)	16	5·7	15	5·5	14	6·4
Sex (% male)	53		53		47	
LAZ	−2·2	1·3	−2·0	1·1	−2·0	1·2
Stunted (%)	49		51		52	
WAZ	−1·2	1·1	−1·1	0·9	−1·0	1·0
Underweight (%)	18		12		14	
Diarrhoea symptoms in previous two weeks (%)	38		42		41	
Maternal characteristics						
Age (years)	31	7·7	30	8·3	30	7·1
Height (cm)	150	4·7	150	5·0	149	5·6
Parity*	5·6	2·7	4·4	2·5	4·2	2·5
Education (% not completing primary school)	96		93		87	
Antenatal care attendance (% never attended during most recent pregnancy)	50		39		40	
ICFI score	6·9	1·9	7·1	1·9	7·4	1·8
Household characteristics						
Access to electricity (% with access)*	12		34		25	
Number of children in household	4·2	2·1	3·5	2·0	3·1	1·8
Cultivated land area (ha)*	0·88	1·20	0·66	0·52	0·58	0·58
Crop diversity of household farm*	6·2	2·2	6·9	1·8	5·8	2·0
Distance to nearest health facility (hours by foot)*	2·0	1·1	1·9	1·1	2·4	1·3
Number of sheep and goats owned	29	20	29	13	26	20

	6–11 months		12–23 months	
IYCF practices	Mean	SD	Mean	SD
Child received breast milk (24 h) (%)	98		76	
Duration of exclusive breast-feeding (months)	3·2	1·9	3·4	1·7
Child fed exclusively breast milk to 6 months of age (%)	21		18	
Child was fed using a bottle (24 h) (%)	30		21	
Number of food groups consumed (24 h)	2·4	1·4	3·0	1·2
Number of food groups consumed (7 d)	2·9	1·6	4·0	1·4
Child was fed semi-solid or solid foods (24 h)	64		70	
Number of meals and snacks fed (24 h)	2·1	0·8	2·5	1·0
Child was assisted during eating (24 h) (%)	77		45	
Energy intake from complementary food (kJ)	1500	590	2900	1300
ICFI score	8·3	1·5	6·4	1·7

IYCF, infant and young child feeding; LAZ, length-for-age *Z*-score; WAZ, weight-for-age *Z*-score; ICFI, infant and child feeding index.
Data are presented as means and standard deviations or as proportions.
*Differences across elevation zones significant at $P < 0·05$.
†*n* 251 for the entire sample; *n* 95 children aged 6–11 months; *n* 156 children aged 12–23 months.
‡Elevation (in metres above sea level): low = 2700–3300, *n* 84; mid = 3300–3800, *n* 84; high = 3800–4200, *n* 83.

elevations to 34 % at mid elevations. Mid-elevation households grew a larger diversity of crops (mean 6·9 (SD 1·8)) compared with households at high elevations (mean 5·8 (SD 2·0); $P<0·05$), while households at low elevations cultivated larger land areas (mean 0·88 (SD 1·2) ha) compared with those at high elevations (mean 0·58 (SD 0·58) ha; $P < 0·05$). However, the mean land area cultivated did not exceed one hectare for any elevation zone.

Infant and young child feeding practices

Breast-feeding was practised by nearly all mothers through the first year of life. Mothers of children aged 12–23 months reported exclusively breast-feeding (i.e. feeding the child only breast milk, oral rehydration solution, vitamins, minerals or medicines) for 3·4 (SD 1·7) months (Table 2). Only 18 % of these mothers reported feeding exclusively breast milk until their child was 6 months of age.

The mean number of food groups consumed by children aged 12–23 months as reported in 24 h dietary recalls was 3·0 (SD 1·2). The mean number of food groups consumed in the previous week was higher at 4·0 (SD 1·4). More than three-quarters of children aged 6–11 months were assisted during eating (77 %), although fewer than half of older children were assisted (45 %). Children aged 12–23 months received meals and snacks less than three times daily (mean 2·5 (SD 0·96)).

The mean summary ICFI score was 8·3 (SD 1·5) and 6·4 (SD 1·7) for children aged 6–11 months and 12–23 months,

Table 3 Adjusted regression coefficients from models performing the regression of LAZ, energy consumption and MMDA *v.* the summary ICFI and ICFI component indicators, northern region of Potosí department, Bolivian Andes, March 2009†,‡

Response variables	LAZ			Energy (kJ)			MMDA		
Child age range (months)	6–11	12–23	6–23	6–11	12–23	6–23	6–11	12–23	6–23
ICFI summary indicator									
ICFI tertiles									
Mid	0·22$^{(*)}$	0·31*	0·38*	950$^{(*)}$	850*	810*	10	3·4	2·3
High	0·35*	0·44**	0·47**	1400*	1900**	1500**	24*	5·3*	7·2*
ICFI component indicators									
Breast-feeding (24 h)									
Yes	−0·26	−0·20	−0·20	−1000	−500	−730	−6·8	−5·6	−11
Bottle use (24 h)									
Yes	−0·07	−0·10	−0·09	−310	−330	−440	−7·4	−3·7	−5·2
Food group diversity (24 h)									
Mid	0·11	−0·04	0·01	1500*	5700	440	4·5$^{(*)}$	2·9$^{(*)}$	3·3
High	0·34	0·03	0·22	2000**	870*	920**	7·1*	4·8*	5·1*
Food group frequency (7 d)									
Mid	−0·10	0·39*	0·18*	230	230	180	2·5	1·8	2·2
High	0·22$^{(*)}$	0·46*	0·38*	220	260	210	4·3	3·1	5·3
Food consistency (24 h)									
Semi-solid or solid foods	0·16	0·39*	0·28*	670*	1200*	1000*	14*	5·8*	6·5*
Feeding frequency (24 h)									
Mid	0·23	0·40$^{(*)}$	0·45*	1000$^{(*)}$	1600*	1500**	3·2	2·1	1·9
High§	0·38*	0·56*	0·62*	1600**	3200*	3200**	6·4	1·4	4·7
Responsive feeding (24 h)									
Yes	0·43*	0·33*	0·43*	170	530*	420$^{(*)}$	0·8	1·2	1·7

LAZ, length-for-age *Z*-score; ICFI, infant and child feeding index; MMDA, mean micronutrient density adequacy.
$^{(*)}P<0·1$; $^{*}P<0·05$; $^{**}P<0·01$.
†*n* 251 children aged 6–23 months; *n* 95 children aged 6–11 months; *n* 156 children aged 12–23 months.
‡The following covariates were included in each model with the exception that maternal height was only included in models using child LAZ as the dependent variable: child age, child sex, child reported to have diarrhoea symptoms in the previous two weeks, maternal height, maternal education and household socio-economic status (using two rotated factors derived from factor analysis).
§The highest two scores for the feeding frequency indicator were combined in the 'high' category shown for children aged 12–23 months.

respectively. The Cronbach's α coefficient of the ICFI was 0·67 including all children aged 6–23 months.

Association of infant and child feeding index with child length-for-age Z-score

In multiple regression models controlling for variables that could potentially confound the relationship between child feeding practices and child LAZ, the summary ICFI demonstrated a positive association with child LAZ such that increasing tertiles of the ICFI were associated with higher LAZ in children 6–11 months, 12–23 months and 6–23 months of age combined ($P<0·05$; Table 3). The mean difference in LAZ between children aged 6–23 months in the high ICFI tertile compared with the low ICFI tertile was 0·47. Neither the breast-feeding and bottle-feeding component indicators of the ICFI, nor the 24 h food group diversity indicator were associated with child LAZ. However, several component scores of the ICFI were positively associated with child LAZ. The 7 d food group frequency and 24 h feeding frequency indicators showed positive associations with child LAZ in children 12–23 months and 6–23 months of age ($P<0·05$). Children who were fed semi-solid or solid foods in the previous 24 h or who were assisted during eating had higher LAZ than children fed only liquids or not assisted during eating. Among the covariates included in the regression models, child age was consistently negatively associated with child LAZ ($P<0·01$) although no other covariates were associated with child LAZ in the models (data not shown). We also tested the interactions of maternal education with the summary ICFI and household SES with the summary ICFI. The interaction terms were not statistically significant and were therefore not included in final models.

Association of infant and child feeding index with child energy intake and dietary micronutrient adequacy

In multiple regression analyses controlling for variables that could potentially confound the relationship between child feeding practices and energy intake or the micronutrient adequacy of diets, the summary ICFI was positively associated with both child energy intake (kJ) and MMDA (Table 3). The 24 h food group diversity and food consistency indicators were positively associated with both energy intake and MMDA. The feeding frequency indicator was positively associated only with energy intake, as was the responsive feeding indicator ($P<0·05$). No other component indicators of the ICFI were associated with energy intake or MMDA. Among the covariates included in the regression models, child age was positively associated with energy intake and MMDA in all models ($P<0·001$) although no other covariates were associated with either outcome. The same interaction

Table 4 Adjusted regression coefficients from models performing the regression of the summary ICFI score *v.* potential determinants of IYCF practices, northern region of Potosí department, Bolivian Andes, March 2009

Response variable	ICFI (continuous summary score)		
Child age range (months)	6–11	12–23	6–23
Child-level factors			
Child age (months)	−0·12*	−0·7*	−0·15**
Child sex (ref. = male)	0·15	0·22	0·37
Child illness (ref. = no occurrence of diarrhoea in previous two weeks)	−0·43	−0·27	−0·16
Maternal-level factors			
Mother's education level (ref. = low)†			
Mid	0·36	0·49	0·64
High	0·51	0·72	0·84*
Maternal knowledge of recommended IYCF practices	0·13	0·13	0·11
Household-level factors			
Number of children in household	−0·18*	−0·16**	−0·18**
Household access to electricity (ref. = no access)	0·03	0·07	0·13
Distance to nearest health facility (hours by foot)	−0·18	−0·10	−0·13
Household food insecurity (HFIAS score)	−0·07	−0·01	−0·04
Number of livestock owned by household	0·02**	0·03**	0·02**
Crop diversity of household farm	interaction	interaction	interaction
Amount of agricultural land cultivated (ha)	−0·19(*)	−0·33*	−0·24*
Elevation at homestead location (ref. = mid elevation, 3300–3800 masl)			
Low (2700–3300 masl)	interaction	interaction	interaction
High (3800–4200 masl)	interaction	interaction	interaction
Interaction terms			
Crop diversity × elevation at homestead location			
Low elevation	0·17	0·32(*)	0·13(*)
High elevation	0·27*	0·46**	0·25*

ICFI, infant and child feeding index; ref., reference category; IYCF, infant and young child feeding; HFIAS, Household Food Insecurity Access Scale; masl, metres above sea level.
(*)$P<0·1$; *$P<0·05$; **$P<0·01$.
†Mother's education level: 'low' = no schooling or did not complete primary school; 'mid' = completed primary school, but no higher; 'high' = completed some schooling after primary school.

terms were tested in these models as in models using child LAZ as the outcome variable, but were similarly not statistically significant and not included in final models.

Determinants of infant and young child feeding practices

In multiple regression analyses performing the regression of the summary ICFI score *v.* potential determinants of child feeding practices, child age was consistently negatively associated with the ICFI ($P<0·05$; Table 4). Maternal-level characteristics were not strongly associated with the ICFI. Mothers of children aged 6–23 months completing schooling beyond primary school did show higher scores on the ICFI compared with mothers completing no school or only some primary school ($P<0·05$). The number of children in households and the amount of agricultural land cultivated by households were negatively associated with the ICFI ($P<0·05$), whereas the number of livestock owned by households was positively associated with the ICFI score ($P<0·01$). Based on differences in household characteristics observed across elevation zones, we hypothesized that the influence of agricultural production and livelihood factors on child feeding practices may differ depending on the elevation zone within which the household was located. We examined the interaction of household elevation with household food security, crop diversity of the household farm, livestock ownership and amount of agricultural land cultivated. In models that excluded any interaction terms, crop diversity was positively associated with the ICFI score ($P<0·05$; data not shown). However, crop diversity also interacted with household elevation such that the crop diversity was more positively associated with child feeding practices in households at high elevations as compared with mid elevations (Table 4).

Discussion

Summary of findings

After controlling for several potential confounding variables, IYCF practices as measured by an ICFI showed positive associations with child LAZ (mean difference of 0·47 in LAZ between children aged 6–23 months in the high ICFI tertile compared with the low ICFI tertile), child energy intake (mean difference of 1500 kJ between high and low ICFI tertiles) and the micronutrient adequacy of child diets (mean difference of 7·2 % in MMDA between high and low ICFI tertiles). Examining determinants of IYCF practices as measured by the ICFI, mother's education, livestock ownership and the crop diversity of household farms were positively associated with the summary ICFI while amount of agricultural land cultivated was negatively associated with the ICFI. The association between crop diversity and child feeding practices was more strongly positive among households at high elevations (i.e. 3800–4200 masl) compared with households at mid elevations (i.e. 3300–3800 masl).

Associations of infant and child feeding index with child anthropometry and measures of dietary adequacy

The finding of a positive association between the ICFI and child LAZ in this Bolivian population aligns well with previous studies that have examined the relationship between summary child feeding indices and child anthropometric outcomes. Results from these studies generally show that in multiple regression analyses controlling for potential determinants of child anthropometric status, the ICFI is positively associated with child length/height-for-age *Z*-score, especially in rural populations (Table 5). The adjusted effect size of 0·47 in LAZ found in the current study (i.e. the difference in mean LAZ of children of caregivers in the lowest tertile of the ICFI compared with those in the highest tertile) is similar to the range of effect sizes reported in previous studies of 0·26 to 0·55 in height-for-age *Z*-score.

The breast-feeding and bottle-feeding component indicators of the ICFI were not associated with child LAZ, child energy intake or MMDA (Table 3). It is possible that these indicators lack sensitivity and do not adequately capture the dynamics of the behaviours they seek to describe. Alternatively, the assumption of an average, age-specific breast milk intake for all children in the sample when calculating the recommended energy intakes from complementary foods for the MMDA may have dampened the relationship observed between breast-feeding and MMDA. Reverse causality, whereby smaller children are perceived as more vulnerable and are weaned later[38,39], may explain the negative relationship observed between continued breast-feeding and child LAZ.

The frequency of feeding different food groups throughout the previous week was positively associated with child LAZ. Dietary diversity indicators consistently show positive relationships with child LAZ in many contexts[40–42]. Similar to findings from other studies[18,43,44], the number of meals and snacks consumed in the previous day was also positively associated with child LAZ. Women in northern Potosí bear numerous responsibilities both in the home and on the farm that limit the amount of time they can dedicate to child feeding[13]. In this population where young children may only receive complementary foods twice in a day, finding ways to allow mothers to incorporate more frequent feeds into their daily routines may be particularly beneficial for the nutritional status of children. The finding that children who were assisted while eating were more likely to have a higher LAZ than children who were unassisted suggests that creating feeding environments wherein the caregiver is able to assist and actively respond to the needs of the child during feeding is also important.

The association observed between child feeding practices as measured by the ICFI and child LAZ is supported by the finding that the adequacy of child diets based on quantitative dietary recall data was substantially different across ICFI tertiles as well. Energy intakes demonstrated a dose–response relationship across increasing ICFI tertiles for all age groupings such that energy intakes were successively higher in higher tertiles. A greater frequency of feeding meals and snacks throughout the day and feeding semi-solid or solid foods (and therefore very likely more energy-dense foods as compared with liquids) were especially strongly associated with higher energy intakes (Table 3). Furthermore, the overall micronutrient adequacy of diets was also associated with the ICFI in a dose–response manner. As in previous studies that showed a positive association between more diverse diets and adequate micronutrient intakes[45,46], more diverse diets in the current study were associated with higher MMDA. Overall, these patterns of associations, similar to those found in previous analyses in Latin American countries[17], indicate that the ICFI in our study may be an appropriate metric for assessing overall child feeding practices in this region of Bolivia.

Determinants of infant and young child feeding in the Bolivian highlands

The quality of IYCF practices was associated with several household-level indicators of wealth and social standing including the education level of the mother, the number of livestock owned by the household and the size of the household. Although more highly educated mothers showed more positive child feeding practices than those with less education, this relationship was not strong. This may be due to the marked homogeneity in levels of maternal education across the sample. The large majority of mothers in the sample never attended or completed primary school (Table 2). More than education, however, community leaders during formative research interviews identified livestock ownership as the main indicator of household wealth and social standing in the study region. Not surprisingly then, this variable was positively associated with child feeding practices. Measures of household SES have been shown to be associated with the quality of feeding behaviours, especially dietary diversity[47,48] and child anthropometric outcomes[49], in other settings.

Two indicators of farm system management and agricultural livelihoods also emerged as associated with the quality of child feeding practices, independent of other household SES factors (e.g. access to electricity and distance to health services). The crop diversity of household farms and the total amount of agricultural land dedicated to cultivating crops were both associated with

Table 5 Studies examining the association between an ICFI and child anthropometry

Country and reference	Sample characteristics	ICFI scale and components†	ICFI association with child anthropometry‡
Ghana[26]	475 children aged 4–36 months (urban)	−11 to 2 point scale	p HAZ (4–36 months)
	HAZ: −0·93	Prelacteal feeds, BF, various foods given 0–4 months, first food offered, feeding assistance, RF	ES: HAZ (only mothers with no education)
	Stunting: 17 %		
Ethiopia[18]	4624 children aged 6–35 months (rural/urban)	0–9 point scale	p HAZ 12–36 months (rural)
	HAZ: not reported	BF, BU, DD (8), FGF (7), MF	ø HAZ 12–36 months (urban)
	Stunting: 46 % (<3 years, rural)		ES: 0·35 HAZ (12–35 months)
Latin America (five countries)[17]	6347 children aged 6–35 months (rural/urban)	0–12 point scale	p HAZ (12–35 months)
	HAZ: not reported	BF, BU, DD (6), FGF (4), MF	ES: 0·5 HAZ (12–35 months)
	Stunting: 12·3–42·1 %		
China[51]	4127 children aged 6–23 months (rural/urban)	0−13 point scale	(unadjusted results)
	HAZ: −0·82 (12–23 months)	BF, 1 month DD (6)	p HAZ
	Stunting: not reported		p WAZ (9–23 months)
			ES: 0·46 HAZ (lowest tertile *v.* highest 2 tertiles)
Senegal[52]	543 children aged 12–42 months (rural)	0–12 point scale	ø HAZ
	HAZ: −1·02	BF, BU, DD (6), FGF (3), MF	ES: −0·19 HAZ (unadjusted)
	Stunting: not reported		
Côte d'Ivoire[53]	557 children aged 6–17 months (urban)	0–12 point scale	(unadjusted results)
	HAZ: −0·76 to 1·11 (12 months)	Milk source, DD (4), FGF (4), MF	Low *v.* average or high ICFI tertile at 6 months associated with lower HAZ at 12 and 18 months
	Stunting: not reported		ES: 0·34 (12 months)
Burkina Faso[43]	2466 children aged 6–35 months (rural)	0–9 point scale	p HAZ 6–23 months
	HAZ: not reported	BF, BU, MF, FV (8), DD (8)	n HAZ 24–35 months
	Stunting: 52 %		n WHZ 6–11 months
			p WHZ 12–23 months
			ES: 0·43 HAZ (12–23 months)
India[54]	204 children aged 6–23 months (urban)	Index scale not reported	ø HAZ 6–23 months
	HAZ: not reported	BF, DD (food groups not reported), MF, psychosocial care, hygiene during preparation and feeding	ø WAZ 6–23 months
	Stunting: 50·5 %		ES: not reported
Madagascar[55]	363 children aged 6–26 months (urban)	0–9 point scale	ø LAZ
	HAZ: −2·18 (12–17 months)	BF, BU, DD (7), FGF (7), MF	p LAZ (longitudinal ICFI)
	Stunting: 58 % (12–17 months)		ø WLZ
			ES: 0·5 LAZ (longitudinal ICFI)
India[56]	151 children aged 6–11 months (rural)	3–23 point scale	p LAZ
	HAZ: not reported	BF, BU, DD (7), initiation of CF, FGF (7), MF	ø WAZ
	Stunting: 24·5 %		
Madagascar[30]§	1589 children aged 6–23 months (urban)	0–9 point scale	p HAZ (6–8 months)
	HAZ: not reported	BF, BU, DD (7), FGF (7), MF	ø HAZ (12–23 months)
	Stunting: 47 %		ES: 0·65 (6–8 months), 0·1 HAZ (12–23 months)
China[44]	3419 children aged 6–23 months (rural)	0–14 point scale	p HAZ
	HAZ: −0·56	BF, BU, DD (6), FGF (4), MF	p WAZ
	Stunting: 13·8 %		ES: 0·26 HAZ

Table 5 *Continued*

Country and reference	Sample characteristics	ICFI scale and components†	ICFI association with child anthropometry‡
China[57]	501 children aged 6–11 months (rural)	0–15 point scale	ø LAZ
	HAZ: 0·01	BF, BU, DD (6), 24 h frequency of staple consumption, FGF (3), MF	p WAZ
	Stunting: 3·2 %		p WLZ ES: 0·15 WAZ
Bangladesh[58]	259 children aged 6–23 months (urban)	0–9 point scale	p LAZ
	LAZ: −2·39 Stunting: 60 %	BF, BU, DD (7), FGF (7), MF	ø WAZ ø WLZ ES: not reported
Senegal[59]	1060 children aged 6–36 months (rural)	0–7 point scale	p HAZ (6–11 months, 18–23 months)
	HAZ: −1·20 (SD 1·2) (first visit)	BF, MF, DD (7), FV (20)	p Linear growth over 6-month period (18–23 months)
	Stunting: 23·3 %		ES: 0·97 HAZ (6–11 months), 0·37 HAZ (18–23 months)
China[27]	180 children aged 5–20 months (urban)	0–10 point scale	p LAZ (5–7 months, 16–20 months)
	LAZ: 0·41 (SD 0·91) (16–20 mo) Stunting: 0·38 %	BF, FC, MF, 7 d DD (8), FGF (8)	p WAZ (5–7 months) p WLZ (5–7 months) ES: 0·26 LAZ (16–20 months, longitudinal ICFI)

ICFI, infant and child feeding index; HAZ, height-for-age *Z*-score; LAZ, length-for-age *Z*-score; BF, 24 h breast-feeding; RF, responsive feeding; BU, 24 h bottle use; DD, 24 h dietary (food group) diversity; FGF, 7 d food group frequency; MF, 24 h meal or feeding frequency; FV, 24 h food variety (individual foods); CF, complementary foods or feeding; FC, 24 h food consistency (liquid *v.* semi-solid); ES, effect size (refers to the difference in the indicator between the lowest and highest ICFI tertiles); WAZ, weight-for-age *Z*-score; WHZ, weight-for-height *Z*-score; WLZ, weight-for-length *Z*-score; MMDA, mean micronutrient density adequacy.
†Values in parentheses after DD and FGF are the maximum number of food groups.
‡'p' indicates a positive association; 'n' indicates a negative association; 'ø' indicates no significant association.
§The ICFI was also positively associated with energy intake and MMDA ($P < 0.0001$).

IYCF practices, albeit in opposite directions. More diverse farms were associated with higher ICFI scores ($P < 0.05$). In sub-analyses we examined the association between crop diversity and the individual component ICFI indicators as well (data not shown). Crop diversity was most strongly associated with the frequency of feeding different food groups in the previous week ($P < 0.05$). However, it was not associated with the 24 h dietary diversity indicator. The 7 d food group frequency indicator may better represent usual diets than the 24 h dietary diversity indicator and therefore more accurately reflect variation in the sample with respect to dietary diversity. For subsistence households such as those in northern Potosí that do not purchase many food items, but rather consume mostly what they produce themselves, diversified production systems may be an important foundation for diversifying household and individual diets. Notably, the association between crop diversity and child feeding practices was more strongly positive among households above 3800 masl where the crop diversity of farms is not as great as at mid elevations (Table 2). At mid elevations, agroclimatic conditions are amenable to planting a wider breadth of crops than is possible in the extreme highlands. This finding suggests that efforts to diversify production systems in subsistence regions with low existing crop diversity may yield especially high returns with respect to diversifying diets.

While diversified agricultural production was positively associated with child feeding practices, the total amount of land devoted to agricultural production was negatively associated with these practices. This may seem counter-intuitive and, indeed, formative research with community leaders indicated that larger agricultural landholdings were indicative of wealthier households. Yet, in-depth interviews with a sub-sample of the caregivers who participated in the study revealed that one of the most salient barriers to improving caregiving and feeding practices was the high burden of agricultural labour that they shouldered[13]. Women in these rural communities are responsible for herding and pasturing animals, planting and harvesting crops, maintaining those crops throughout the growing season, and tending to numerous domestic responsibilities. The negative association between agricultural land area and child feeding practices, then, may well reflect the additional burden of labour placed on women from households cultivating more extensive land areas. Cultivated land area was correlated with the feeding frequency indicator ($P < 0.05$) and modestly correlated with the responsive feeding indicator of the ICFI ($P = 0.07$; data not shown). These findings align with the overwhelming sentiment expressed in the aforementioned qualitative interviews with caregivers that high agricultural labour burdens for women are a considerable barrier to improving the quality of child feeding practices.

Study weaknesses

Previous authors have remarked that child feeding practices may be endogenous to multiple regression models using child anthropometric status as an outcome[17]. No suitable instrumental variables were identified from available data to address this concern and so the problem of endogeneity remains a limitation of these analyses. In addition, families in participating communities self-selected to participate in the household survey. Survey coverage was high, however, with 91 % of eligible families participating. Only one household refused to participate while all other households were not available for interview on any of the days that enumerators visited the community. The high proportion of participating households and the minimal refusals suggest that selection bias did not strongly influence results.

Conclusion

The feeding practices that mothers undertake to care for children in their first years of life are crucial for the healthy growth and development of children. The potential for agriculture to influence these practices is substantial. Diversifying agricultural production may not only help to sustain ecosystem services that support and sustain the natural environment (e.g. soil and water conservation, biodiversity or regeneration of organic materials)[50], but may also positively influence the quality of household and child diets, especially for subsistence farming families. Increasing productivity and enhancing access to market opportunities are also important routes through which agriculture may influence nutrition and food security for smallholder farmers. However, investments in agriculture must recognize the important role of women in supporting healthy children and families as well as vibrant farms. Changes in production scales or farm management practices may improve yields and incomes, but they could also deleteriously impact women's caring capacity, health and nutritional status, especially if changes result in higher labour burdens for women or their loss of control over productive resources. Further research is needed to understand what investments are needed and how to implement them in order to support an agriculture that is productive, sustainable and profitable, but also supportive of the health and nutrition of farmers and their families.

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